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A COMPARISON OF BUILDING ENERGY CODE STRINGENCY: 2009 IECC VERSUS 2012 IECC FOR COMMERCIAL CONSTRUCTION IN TEXAS

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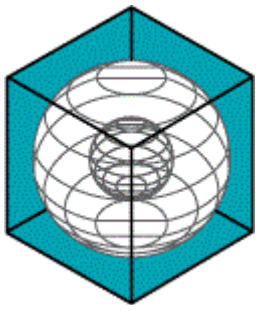

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EXECUTIVE SUMMARY

In 2007, the 80th legislature mandated the Energy Systems Laboratory (Laboratory) to take part in Texas rule-making process. As detailed in the Health and Safety Code, Chapter 388, Texas Building Energy Performance Standards, Sec. 388.003 (b-1), the Laboratory is required to submit written recommendations to the State Energy Conservation Office (SECO) on whether the energy efficiency provisions of the latest published editions of the International Residential Code (IRC) or the International Energy Conservation Code (IECC) for residential or commercial energy efficiency and air quality are equivalent to or more stringent than the provisions of editions previously adopted as the Texas Building Energy Performance Standards (TBEPS).

This report, focusing on Commercial Construction provisions, is in support of the letter of recommendation sent to the State Energy Conservation office on December 8, 2011. The report provides a detailed technical analysis comparing the stringency of the Texas Building Energy Performance Standards (TBEPS), based on the 2009 International Energy Conservation Code (2009 IECC), Chapter 5, to the recently published 2012 International Energy Conservation Code (2012 IECC), Chapter 4 (CE).

The technical analysis was performed in two steps:

(a) Performing a desk-check, comparing the sections related to commercial compliance in the two codes. The results of the desk-check indicate that for most sections the 2012 IECC is more stringent than the 2009 IECC.

(b) Conducting a simulation analysis in which a commercial office building complying with the 2009 IECC is compared to a similar building that complies with the 2012 IECC. This analysis was conducted for three climate zones which represent the entire state of Texas. The results of this analysis indicate that for the case of large office buildings, the 2012 IECC is more stringent that the 2009 IECC. When considering the site energy consumption, the large office building complying with the 2012 IECC consumes 7% to 12% less site energy on an annual basis than the office building complying with the 2009 IECC, depending on the climate zone in which the building is located. When considering the source energy consumption, the large office building complying with the 2012 IECC consumes 4% to 6% less source energy on an annual basis than the office building complying with the 2009 IECC, depending on the climate zone in which the building is located.

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1. ORGANIZATION OF THE REPORT

This report is organized in the following order.

- Section 1 presents the organizational structure of the report.
- Section 2 presents the introduction and purpose of the report.
- Section 3 presents the results of a desk-check conducted for commercial provisions in the 2009 and the 2012 IECC.
- Section 4 describes a set of simulation runs which compares a 2009 IECC code-compliant large office building with a corresponding 2012 IECC code compliant building.
- Section 5 provides the conclusions of the analysis conducted.

2. INTRODUCTION

This report presents the results of a detailed technical analysis comparing the stringency of the Texas Building Energy Performance Standards (TBEPS), based on Chapter 5 of the 2009 International Energy Conservation Code (2009 IECC) for commercial construction to Chapter 4 (CE) of the 2012 International Energy Conservation Code (2012 IECC). The purpose of this comparison is to assess the stringency of the 2012 IECC when compared to 2009 IECC for the three climate zones representing the state of Texas – climate zone 2 (A & B), climate zone 3 (A & B) and climate zone 4B. During this process, the report will attempt to verify that the 2012 IECC is more stringent than the 2009 IECC. The comparison is executed in two steps. As a first step, an in-depth desk-check is performed making a section by section assessment of the commercial provisions in the two codes. Comments are provided assessing the stringency for each section. These comments are specific to the three climate zones of Texas. For the second step, a simulation is performed comparing the 2009 IECC with the 2012 IECC considering the example of a large office building. The analysis is performed for the three counties, representing the three climate zones in Texas: Harris (Climate Zone 2A), Tarrant (Climate Zone 3A) and Potter (Climate Zone 4B).

3. STEP 1: Comparing the Commercial Provisions in the 2009 IECC and the 2012 IECC

In order to assess the provisions for commercial buildings in the IECC codes, Chapter 5 of the IECC 2009 is compared to Chapter 4 (CE) of the 2012 IECC. The comparison is provided for the mandatory performance as well as prescriptive sections of the codes. The comparison and the corresponding comments are provided in Tables 1-13 of this report. The tables are arranged using the section structure presented in the 2012 IECC. Comments regarding the stringency of each 2012 IECC section as compared to the corresponding sections in the 2009 IECC code are provided in the comment column of the tables. The last two columns identify whether the modified /added section in the 2012 IECC is less stringent, as stringent, more stringent or not applicable to the prescriptive or performance path followed for code compliance. Comments for mandatory specifications are included in these columns.

The salient changes in the 2012 IECC code include:

- In Section C401, when adopting the performance path for compliance, the building energy cost is now required to be equal to or less than 85 percent of the standard reference design building in order to show compliance;
- In Section C402, the reduction of maximum window and skylight area in the prescriptive section of the 2012 code (From 40% window to wall area ratio(WWAR) to 30% WWAR);
- In Section C403, more stringent efficiency requirements for certain categories of equipment;
- In Section C403, the introduction of more stringent requirements for air economizers;
- In Section C405, the addition of space-by-space method to account for interior lighting power allowances when complying with the lighting section of the code;
- The addition of Section C406 describing additional efficiency package options, which are to be implemented when using the prescriptive path for compliance with the 2012 IECC; and
- The addition of Section C408 describing the system commissioning process has been recompiled from different sections of the 2009 IECC.

The desk-check reveals that there is enough evidence to state that the 2012 IECC is more stringent than 2009 IECC. The sections where the 2012 IECC is less stringent than the 2009 IECC include Section C402.3.3.2, section C402.3.3.3 and Section C402.3.3.4. These sections provide exceptions for the U-values and SHGCs of vertical fenestration and skylights when considering window placement (as in Section C402.3.3.2) and installation of daylighting controls (as in Section C402.3.3.3 and C402.3.3.4). A separate set of simulations was performed to assess the stringency of these sections. It was concluded that these sections are more stringent than the corresponding information in the 2009 IECC. The results are provided in Appendix A of the report.

Table 1: Comparing Section C401 of the 2012 IECC to Section 501 of the 2009 IECC: General Compliance Strategies

Section No.			Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C401 General	C401.2 Application		For Option 1, the 2012 IECC references the ASHRAE Standard 90.1-2010. The ASHRAE Standard-90.1 2010 is more stringent than the ASHRAE Standard90.1-2007 (1).	N.A.	N.A.
			For Option 2, Section C406 - Additional Efficiency Package Options is added in the 2012 IECC. When showing compliance using the prescriptive path, the user is now required to meet the requirements of any one of the subsections in this section in addition to other prescriptive and mandatory requirements.	More stringent	N.A.
			For Option 3, which pertains to provisions for compliance using total building performance, the 2012 code now requires the building energy cost to be less than or equal to 85% of the standard reference design building.	N.A.	More stringent
		C401.2.1 Application to exiting buildings	New language has been added to the code for existing buildings to demonstrate compliance.	As stringent	N.A.

Note 1: The stringency of the ASHRAE Standard-90.1 2010 is provided in an ESL report comparing ASHRAE and IECC standards for large office buildings by Mukhopadhyay et al. (2011).

Table 2: Comparing Section C402 of the 2012 IECC to Section 502 of the 2009 IECC: Building Envelope Requirements

Section No.					Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C402 Building Envelope Requirements	C402.1 General (Pres.)				The 2012 code provides two options for prescriptive compliance of the building thermal envelope with the code by rearranging the language provided in the 2009 IECC code.	As stringent	N.A
	C402.2 Specific insulation requirements (Pres.)				Additional language is included in the 2012 IECC describing the procedure for installing the layers of insulation.	More stringent	N.A
		C402.2.1 Roof assembly			Additional language is included in the 2012 IECC requiring insulation of skylight curbs.	More stringent	N.A
			C402.2.1.1 Roof solar reflectance and thermal emittance		This section requires compliance for minimum roof reflectance and emittance (Table: C402.2.1.1).	More stringent	N.A
				Table C402.2.1.1 Minimum Roof Reflectance and Emittance Options	This table has been added to the 2012 code to support the added section C402.2.1.1. The table provides minimum requirements for roof reflectance and emittance.	More stringent	N.A
		C402.2.6 Slab on grade			The exception provided in the 2012 code for this section removes the requirement of slab insulation when the position of the slab is greater than 24 inches below the finished exterior grade.	As stringent	N.A
				Table C402.1.2 Opaque Thermal Envelope Assembly Requirements (Perf.)	Most of the values are more stringent for the climate zones considered.	More stringent	More stringent
				Table C402.2 Opaque Thermal Envelope Requirements (Pres.)	Most of the values are more stringent for the climate zones considered.	More stringent	N.A
		C402.2.8 Insulation of radiant heating systems			Minimum specifications for insulation of radiant heating devices has been added in this section of the 2012 IECC.	More stringent	N.A

Table 3: Comparing Section C402 of the 2012 IECC to Section 502 of the 2009 IECC: Building Envelope Requirements Continued …

A					Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C402 Building Envelope Requirements	C402.3 Fenestration (Pres.)				Language has been added in the 2012 code to incorporate daylighting controls to this section.	More stringent	N.A
		C402.3.1 Maximum area			The value of maximum fenestration area is reduced from 40% WWAR as prescribed in the 2009 code to 30% WWAR with an allowance to increase fenestration area to 40% WWAR provided daylight controls are installed.	More stringent	N.A
			C402.3.1.1 Increased vertical fenestration				
			C402.3.1.2 Increased skylight area with daylight control		Similarly for skylights, the area is allowed to increase to 5% of the total roof area provided daylight controls are installed.	More stringent	N.A
				Table C402.3 Building Envelope Requirements: Fenestration (Pres. + Perf.)	The fenestration and skylight U-values specifications in the 2012 code are more stringent than the corresponding specifications in the 2009 code. This table is simplified from the corresponding table in the 2009 code.	More stringent	More stringent
		C402.3.2 Minimum skylight fenestration area			The 2012 code provides minimum requirements for skylights for certain building types and area. No such requirements based on building types and area are provided in the 2009 code.	More stringent	N.A
			C402.3.2.1 Lighting controls in daylight zones under skylights		Requirements are added in the 2012 code to implement multilevel lighting controls for lighting in daylit zones.	More stringent	N.A
			C402.3.2.2 Haze factor		The 2012 code introduces a haze factor for skylights for certain situations such as offices and retail stores.	More stringent	N.A
			C402.3.3.1 SHGC adjustment		Adjustment to SHGC are provided in the 2012 code for cases where the projection factor is greater than 0.2.	As stringent	N.A
				Table C402.3.3.1 SHGC Adj. Mult.	The table specifying multipliers for SHGC adjusment is added in the 2012 code.	As stringent	N.A
			C402.3.3.2 Increased vertical fenestration SHGC		In the 2012 code, the exception for SHGC is raised to 0.4 in climate zone 1,2 and 3 for vertical fenestration greater than 6 feet above the finished floor level. It is a good strategy to get in more light but its less stringent as there is no such exception in the 2009 code.	As stringent (2)	N.A
			C402.3.3.3 Increased skylight SHGC		Exception for SHGC to be raised to 0.6 in climate zone 1 through 6 for cases where automatic daylight controls are installed.	As stringent (2)	N.A
			C402.3.3.4 Increased skylight U-factor		Exeption for U-factors are provided for cases where automatic daylight controls are installed. This strategy may not be suitable for higher climate zones where low U-values play an important role in reducing the energy consumption.	As stringent (2)	N.A
			C402.3.3.5 Dynamic glazing		Provisions for dynamic glazing have been added to the 2012 code.	More strigent	N.A
		C402.3.4 Area-weighted U-factor			Language has been added to the 2012 code to incorporate area weighted averages for U-values of fenestration.	As stringent	N.A

Note 2: The stringency of these sections is assessed in Appendix A of this report.

Table 4: Comparing Section C402 of the 2012 IECC to Section 502 of the 2009 IECC: Building Envelope Requirements Continued …

Section No.					Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C402 Building Envelope Requirements	C402.4 Air leakage (Mandatory)	C402.4.1 Air barriers	C402.4.1.1 Air barrier construction		The 2012 code requires a provision of continious air barriers. However, climate zones 1, 2 and 3 are exempt from this requirement.	As stringent	As stringent
			C402.4.1.2 Air barrier compliance options	C402.4.1.2.1 Materials			
				C402.4.1.2.2 Assemblies			
				C402.4.1.2.2 Building test			
		C402.4.2 Air barrier penetration			Requirements for treatment of air barrier penetrations has been added in the 2012 code.	More stringent	More stringent
		C402.4.3 Air leakage of fenestration			Maximum air infiltration rate for fenestration assemblies are provided in Table C402.4.3. The max rate for windows is 0.2 cfm/ sq.ft. No values are prescribed for windows in the 2009 code. Max. infiltration values for other fenestration components are as stringent or more stringent that the values prescribed in the 2009 code.	More stringent	More stringent
		C402.4.4 Doors and access opening to shafts, chutes, stairways and elevator lobbies			Section added in 2012 code which provides specifications to reduce infiltration in doors and access openings to shafts, chutes, stairways and elevator lobbies.	More stringent	More stringent No impact on simulation
		C402.4.5 Air intakes, exhaust openings, stairways and shafts	C402.4.5.1 Stairway and shaft vents		Section added in 2012 code which reorganizes the specifications provided in the 2009 code to reduce infiltration in air intakes, exhaust openings,stairways and shafts. Although the requirements remain the same, exceptions are added in the 2012 code to ensure more efficient operation of the outdoor air intakes and exhausts.	More stringent	More stringent No impact on simulation
			C402.4.5.2 Outdoor air intakes and exhausts				
		C402.4.7 Vestibules			Language added in the 2012 code requiring vestibules for all building entrances (with certain exceptions). Additional language has been added addressing the case of revolving doors.	More stringent	More stringent No impact on simulation
		C402.4.8 Recessed lighting			Section has been reworded in the 2012 code.	As stringent	As stringent No impact on simulation

Table 5: Comparing Section C403 of the 2012 IECC to Section 503 of the 2009 IECC: Building Mechanical Systems

Section No.					Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C403 Building Mechanical Systems		C403.2.1 Provisions applicable to all mechanical systems			New language added in the 2012 code to account for loads from the building envelope, lighting ventilation and occupancy.	As stringent	As stringent
		C403.2.2 Equipment and system sizing			New language in the 2012 code pointing to the previous section.	As stringent	As stringent
		C403.2.3 HVAC equipment performance requirements			New equipment has ben added to the 2012 code. These include specifications for plate type heat exchangers and cooling towers.	More stringent	More stringent
				Table 403.2.3 (1) - (7)	Information in tables have been updated for more stringent specifications. New information has been added to incorporate a greater variety of equipment. Some efficiencies are specified by climate zones.	More stringent	More stringent
				Table 403.2.3(8) Minimum Efficiency Requirements: Heat Rejection Equipment	This table has been added to the 2012 code. The table provides specifications for water cooled heat rejection equipment.	More stringent	N.A.
			C403.2.3.1 Water cooled centrifugal chilling packages		This section has been converted from an exception in the earlier code. This section provides guidelines to calculate the adjustment factor in the case of chilled water temperatures being different. The formula is different than that specified in the 2009 code.	More stringent	More stringent
			C403.2.3.2 Positive displacement chilling packages		This section has been added in the 2012 code to provide specifications for positive displacement chilling packages in the case their operating conditions do not meet the specified requirements.	As stringent	As stringent
		C403.2.4 HVAC system controls	C403.2.4.3 Off-hour controls	C403.2.4.3.3 Automatic start capabilities	The 2012 code provides for automatic start capabilities when considering for off-hour controls. The HVAC systems are now required to incorporate controls that are capable of automatically adjusting the daily start time of the HVAC system in order to bring the space the system is serving to the desired occupied temperature.	More stringent	As stringent
		C403.2.5 Ventilation	C403.2.5.1 Demand controlled ventilation		The average occupancy load has changed from 40 people per 1000 sqft to 25 people per 1000 sqft for the implementation of demand control ventilation. Hence this measure will be used in many more cases. A new exception has been added exempting ventilation provided for process loads only.	More stringent	More stringent

Table 6: Comparing Section C403 of the 2012 IECC to Section 503 of the 2009 IECC: Building Mechanical Systems Continued …

Section No.					Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C403 Building Mechanical Systems		C403.2.6 Energy recovery ventilation systems			In this section a table has been added for minimum requirements for each zone. The provision in the 2009 code requiring energy recovery ventilation systems for fans with 70% of outdoor air at full design airflow rate and 5000 cfm of design supply air rate has been removed. Depending on the climate zone, energy recovery is required when outdoor air percentage is greater than or equal to 30%. Several exceptions have been added which include exceptions specific to climate zones, operation time etc.	More stringent	More stringent
				Table C403.2.6 Energy Recovery Requirements	This table has been added elaborating the energy recovery requirements for different % of outdoor air at full design airflow rate and climate zones.	More stringent	More stringent
		C403.2.8 Piping insulation			Exceptions have been added for piping insulation requirements specified in Table C403.2.8 of the code. These include piping that conveys fluids that have temperatures btwn 60 F and 105 F, Values meeting certain specifications and certain types of direct buried piping.	As stringent	As stringent
			C403.2.8.1 Protection of piping insulation		Language added requiring protection of piping insulation from sunlight, moisture, equipment maintenance and wind.	More stringent	More stringent
		C403.2.9 Mechanical system commisioning and completion requirements			Commissioning now required and carried out as per Section C408.2 of the code.	More stringent	More stringent
			C403.2.10.1 Allowable fan floor horsepower		Language has been added in the 2012 code for single zone variable air volume systems to comply with the constant volume fan power limitations. This definitly makes the fan power limitation for these systems more stringent.	More stringent	More stringent
				Table C403.2.10.1(1) Fan Power Limitations	Definition for CFM_D added in the 2012 code.	As stringent	As stringent
				Table C403.2.10.1(2) Fan Power Lim. Pr. Drop Adj.	More information regarding certain equipment such as biosafety cabinets, energy recovery devices, laboratory and vivarium exhaust systems has been added in the 2012 code.	More stringent	More stringent

Table 7: Comparing Section C403 of the 2012 IECC to Section 503 of the 2009 IECC: Building Mechanical Systems Continued …

Section No.					Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C403 Building Mechanical Systems		C403.3.1 Economizers			Economizers serving unitary or packaged HVAC equipment are now described by specifications in Table C403.3.1(1). Certain exceptions have been added which include operation time, system capacity of residential spaces, process requirements and type of equipment being installed.	More stringent	More stringent
				Table C403.3.1(1) Economizer Requirements	Climate zones 2A, 7 & 8 now require economizers. The requirements for economizers have been changed from ≥ 54,000 Btu/hr to ≥ 33,000 Btu/h. Footnote setting maximum limits for requirement of total capacity of all systems without economizers changed from 480,000 Btu/hr to 300,000Btu/hr.	More stringent	More stringent
			C403.3.1.1 Air economizers		More detail has been introduced in the selection of economizers using system sizing and climate zone in which the system is located as selection criteria.	More stringent	More stringent
				C403.3.1.1.1 Design capacity			
				C403.3.1.1.2 Control signal			
				C403.3.1.1.3 High-limit shutoff			
				Table C403.3.1.1.3 High-limit Shutoff Control Options for Air	The table for high limit shut-off options for air economizer controls has been introduced.	More stringent	More stringent
				Table C403.3.1.1.3 High-limit Shutoff Control Setting for Air	The table for high limit shut-off settings for air economizer controls has been introduced. Requirements for design capcity of economizers and controls have been specified.	More stringent	More stringent

Table 8: Comparing Section C403 of the 2012 IECC to Section 503 of the 2009 IECC: Building Mechanical Systems Continued …

Section No.					Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C403 Building Mechanical Systems		C403.4.1 Economizers			Language for design capacity, maximum pressure drop, integrated economizer control to provide for partial cooling and provisions for economizer not to impact the heating system, have been added to the 2012 code for economizers used in complex HVAC systems.	More stringent	More stringent
			C403.4.1.1 Design capacity			More stringent	More stringent
			C403.4.1.2 Max. pressure drop			More stringent	More stringent
			C403.4.1.3 Integrated ecomonizer control			More stringent	More stringent
			C403.4.1.4 Economizer heating system impact			More stringent	More stringent
		C403.4.2 Variable air volume fan control			Language for VAV fans for complex HVAC systems has been added in the 2012 code to include the type of fan to be used: vane-axial with variable pitch blades.	More stringent	N.A.
			C403.4.2.1 Static pressure sensor location		Language has been added to determine the position of static pressure sensors.	More stringent	N.A.
		C403.4.3 Hydronic system controls	C403.4.3.3 Hydronic heat pump systems	C403.4.3.3.2.2 Climate zones 5 through 8	Section reworded in the 2012 code to describe heat rejection criteria for climate zones 5 through 8.	As stringent	N.A.

Table 9: Comparing Section C404 of the 2012 IECC to Section 504 of the 2009 IECC: Service Water Heating

Section No.			Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C404 Service Water Heating (Mandatory)			Certain subsections have been introduced or rewritten from the 2012 IECC code. However, the changes to these sections have an impact only if following the prescriptive path.	As stringent	As stringent No impact on simulation
	C404.5 Pipe insulation		Exception added in the 2012 code for heat-traced and untraced piping systems.	As stringent	As stringent No impact on simulation
	C404.6 Hot water system controls		In addition to the specifications in the 2009 code, the 2012 code requires easy accessability of the controls.	As stringent	As stringent No impact on simulation
	C404.7 Pools and inground permanently installed spas	C404.7.1 Heaters	The requirements in the 2012 code now encompasses pool as well as inground permanently installed spa heaters.	As stringent	As stringent No impact on simulation
		C404.7.2 Time switches	Requirements for time switches have been added for all heaters and pumps.	As stringent	As stringent No impact on simulation
		C404.7.3 Covers	Insulation specifications for pool cover have been removed. However the exception to this sections sets a higher limit to the energy requirements of the pool to be met by renewable on-site resources in order to avoid requirements for pool covers.	As stringent	As stringent No impact on simulation

Table 10: Comparing Section C405 of the 2012 IECC to Section 505 of the 2009 IECC: Electric Power and Lighting

Section No.					Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C405 Electrical Power and Lighting Systems (Mandatory)	C405.1 General				The exception in this subsection is now changed to have more stringent provisions for non-compliance of dwelling units within commercial buildings with this section. The dwelling units are now required to have 75% of permanently installed light fixtures be high efficacy lamps. Initially this percentage was set at 50%.	More stringent	As stringent
	C405.2 Lighting Controls				This section has been reorganized in the 2012 code. The subsections are now organized to provide specifications for manual lighting controls, additional lighting controls, specific application control and exterior lighting control.	As stringent	As stringent
		C405.2.1 Manual Lighting Control			This section is now reorganized to incorporate interior lighting controls and light reduction controls.	As stringent	As stringent
			405.2.1.2 Light reducing controls		Several exceptions have been added for lamps that need not be provided with light reduction controls.	As stringent	As stringent
		405.2.2 Additional lighting controls			This section has been rearranged to include sections on automatic time switch control devices, occupancy sensors and daylight zone control. The addition of specifications for occupancy sensors compensate for the reduction in stringency caused by the removal of the holiday scheduling requirements for automatic light shutoffs.	More stringent	More stringent
			405.2.2.1 Automatic time switch control devices		This section has been modified from the 2009 code removing the building stipulation on building size	More stringent	As stringent
			405.2.2.2 Occupancy sensors		Language regarding the installation of occupancy sensors has been added in the 2012 code. The code now requires sensors to be installed in specific areas such as classrooms, conference / meeting rooms, employee lunch and break rooms, private offices, restrooms, storage rooms and janitorial closets, and other spaces 300 sqft or less enclosed by floor to ceileing partitions.	More stringent	As stringent
			405.2.2.3 Daylight zone control	C405.2.2.3.1 Man. daylighting controls	Several control strategies have been added to the daylight zone control section of the 2012 code. Specifications for daylighting control are much more detailed. These include specifications for manual and automatic daylighting control. A separate section on multi-level lighting control is added to meet the requirements of multi-level lighting control in the 2012 code.	More stringent	As stringent
				C405.2.2.3.2 Auto. daylighting controls			
				C405.2.2.3.3 Multi-level lighting controls			
		405.2.3 Specific applications control			A separate section on specific applications has been added. As per this section, the lighting previously exempt for the power stipulations of the code is now to be controlled.	More stringent	As stringent

Table 11: Comparing Section C405 of the 2012 IECC to Section 505 of the 2009 IECC: Electric Power and Lighting Continued …

Section No.				Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C405 Electrical Power and Lighting Systems (Mandatory)		405.5.2 Interior lighting power		The 2012 code introduces the space by space method for lighting power density to comply with the code.		More stringent for some building types
			Table C405.5.2(1) Interior Lighting Power Allowances: Building Area Method	This table in the 2012 code is almost similar to the corresponding table in the 2009 code. However, there are certain key differences. Lighting power density for office space, retail and ware houses have been reduced. The base additional lighting power provided for retail has been removed making this table more stringent when analyzing retail buildings.	More stringent	More stringent
			Table C405.5.2(2) Interior Lighting Power Allowances: Space by Space Method	New table has been added to this section providing alternative compliance path which shows compliance by a space by space method. Trade-offs are allowed.	More stringent	More stringent

Table 12: Section C406 of the 2012 IECC: Additional Efficiency Package Options

Section No.	Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C406 Additional Efficiency Package Options	This is a new section introduced in the 2012 code. In order to show compliace using the prescriptive path, the user has to comply with either Section 406.2, C406.3 or C406.4 in addition to showing compliance with Sections C402, C403, C404 and C405.	More stringent	N.A.
Tables C406.2 (1 - 6) Efficient HVAC Performance	The tables in this section are more stringent than the table in Section 403 of the 2012 code.	More stringent	N.A.
Tables C406.3 Reduced Interior Lighting Power	The table is more stringent than the table provided in Section 405.5.2(1) of the 2012 code.	More stringent	N.A.
C406.4 On-site renewable energy	The 2012 code requires that total minimum ratings of on-site renewable energy systems to either provide no less than 1.75 Btu or no less than 0.5 W/sq.ft. of conditioned floor area. OR Provide no less than 3% of the energy used within the building for building mechanical and service water heating and lighting. The introduction of requirements for renewable energy generation makes this code more stringent than the 2009 code.	More stringent	N.A.

Table 13: Comparing Section C407 of the 2012 IECC to Section 506 of the 2009 IECC: Total Building Performance

Section No.	Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C407 Total Building Performance	No changes have been made in this section of the 2012 code. However, since this section of the code references other sections which are more stringent, it can be proved that this section is more stringent.	N.A.	More stringent

Table 14: Section C408 of the 2012 IECC: System Commissioning

Section No.	Comments	Compliance Path: Prescriptive	Compliance Path: Performance
C408 System Commisioning	A new section has been created from several subsections of the previous code.		

4. STEP 2: Simulation Analysis for a Large Office Building

For the second step of the comparison, a simulation analysis was carried out with an intent was to quantify the savings that could be obtained from implementing the 2012 IECC. The analysis was performed using the example of a large office building. The performance path approach prescribed in both the 2009 IECC as well as 2012 IECC was used to carry out this analysis. The DOE-2.1e (Winkelmann et al 1993) whole building simulation tool is used for the analysis.

The analysis was performed for the three Texas counties with each county representing a climate zone as categorized by the IECC: Harris (Climate Zone 2A), Tarrant (Climate Zone 3A) and Potter (Climate Zone 4B). These counties cover the major population centers in the State of Texas. Figure 1 presents the climate zones in Texas and the location of the counties considered for this analysis.

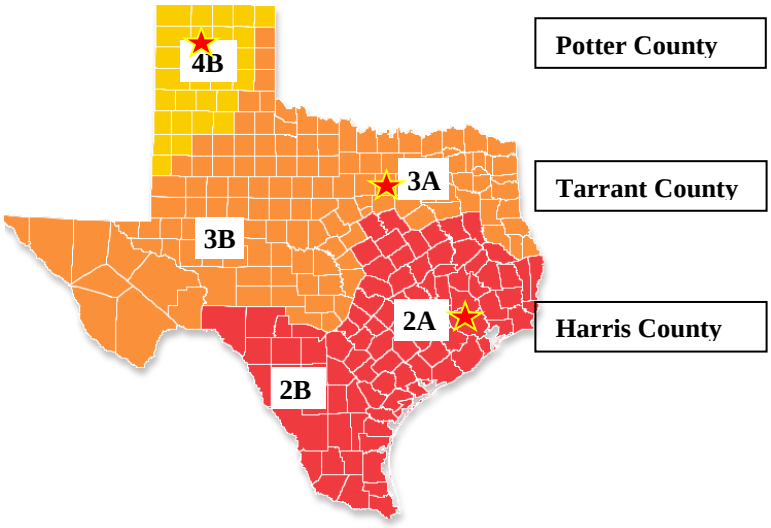


Figure 1: ASHRAE Climate Zones in Texas

For the purpose of this analysis a simulation model had to be constructed. The base-case building is a six story office building as described in studies by Ahmad et al., (2005) and Kim et al., (2009). The aspect ratio is kept at 1.5:1 (Leach et al., 2010). The resulting building dimensions are 149.42 ft. x 99.62 ft. The floor-to-floor height is set at 13 ft. A plenum is modeled for each floor. The height of the plenum is set at four feet. Each floor of the building is divided into four perimeter zones and a central core zone. The perimeter zones face the four orientations and have a width of 15 feet as described in the ASHRAE codes. Table 15 provides certain details for the base-case simulation model as provided in the 2009 IECC and the 2012 IECC. Details are provided for the building envelope, lighting, HVAC systems and service water heating systems implemented in the simulation model. Further details of the base-case model and notes on the modeling assumptions can be found in an ESL report comparing ASHRAE and IECC standards for large office buildings by Mukhopadhyay et al. (2011).

Table 16 and Table 17 present the results from the simulation analysis for site and source energy consumption respectively. The results are graphically presented in Figure 2 and Figure 3. The results for the site energy consumption are reported for each end use, electricity and gas consumption as well as the total energy consumption.

The results for the source energy consumption are reported for electricity and gas consumption as well as the total energy consumption. When reporting the source energy consumption the site electricity consumption is multiplied by 3.15 and the site gas consumption is multiplied by 1.1 as prescribed in the 2009 IECC.

When considering the site energy consumption:

- For Climate Zone 2A, the 2012 IECC provides an improvement of 10% over the 2009 IECC code compliant building.
- For Climate Zone 3A, the 2012 IECC provides an improvement of 7% over the 2009 IECC code compliant building.
- For Climate Zone 4B, the 2012 IECC provides an improvement of 12% over the 2009 IECC code compliant building.

When considering the site energy consumption:

- For Climate Zone 2A, the 2012 IECC provides an improvement of 7% over the 2009 IECC code compliant building.
- For Climate Zone 3A, the 2012 IECC provides an improvement of 4% over the 2009 IECC code compliant building.
- For Climate Zone 4B, the 2012 IECC provides an improvement of 6% over the 2009 IECC code compliant building.

5. Conclusions

A technical analysis was performed to compare the stringency of the Texas Building Energy Performance Standards for commercial construction, based on the 2009 International Energy Conservation Code (2009 IECC), to the recently published 2012 IECC. The comparison of the 2009 IECC commercial provisions (Chapter 5), and the commercial provisions in the 2012 IECC [Chapter 4 (CE)] was a two-step analysis. As a first step, a desk-check was performed comparing the sections related to commercial compliace in the two codes. The results of the desk-check indicate that for most sections, the 2012 IECC is more stringent than the 2009 IECC code. For the second step, a simulation analysis was conducted in which a commercial office building, which complies with the 2009 IECC, is compared to a similar building that complies with the 2012 IECC. The results of the simulation analysis indicate that for the case of large office buildings the 2012 IECC is more stringent than the 2009 IECC.

Table 15: Specifications for the 2009 IECC and 2012 IECC Compliant Large Office Building

Building Component		Climate Zone 2 (A,B) Harris		Climate Zone 3 (A,B) Tarrant		Climate Zone 4B Potter		References	
		IECC 2009	IECC 2012	IECC 2009	IECC 2012	IECC 2009	IECC 2012	IECC 2009	IECC 2012
Envelope									
	Exterior Walls								
	Construction Type	Steel frame	Steel frame	Steel frame	Steel frame	Steel frame	Steel frame	Table 506.5.1(1)	Table C407.5.1(1)
	R-value (h·ft²·°F/Btu)	R-13	R-13 + R-5.0 c.i.	R-13 + R-3.8 c.i.	R-13 + R-7.5 c.i.	R-13 +R-7.5 c.i.	R-13 +R-7.5 c.i.	Table 502.2(1)	Table C402.2
	Roof								
	Construction Type	IEAD (1)	IEAD	IEAD	IEAD	IEAD	IEAD	Table 506.5.1(1)	Table C407.5.1(1)
	R-value (h·ft²·°F/Btu)	R-20 c.i.	R-20 c.i.	R-20 c.i.	R-20 c.i.	R-20 c.i.	R-25 c.i.	Table 502.2(1)	Table C402.2
	Reflectance	0.25	0.25	0.25	0.25	0.25	0.25	Table 506.5.1(1)	Table C407.5.1(1)
	Emittance	0.9	0.9	0.9	0.9	0.9	0.9	Table 506.5.1(1)	Table C407.5.1(1)
	Floor / Slab								
	Consturction Type	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Table 506.5.1(1)	Table C407.5.1(1)
	R-value (h·ft²·°F/Btu)	NR (2)	NR	NR	NR	NR	R-10 for 2' below	Table 502.2(1)	Table C402.2
	Windows								
	Maximum WWR %	40%	40%	40%	40%	40%	40%	Table 506.5.1(1)	Table C407.5.1(1)
	Framing Type	Metal framing	Fixed	Metal framing	Fixed	Metal framing	Fixed		
	U-factor (Btu/h·ft²·°F)	U-0.75	U-0.50	U-0.65	U-0.46	U-0.55	U-0.38	Table 502.3	Table C402.3
	SHGC	0.25	0.25	0.25	0.25	0.40	0.40	Table 502.3	Table C402.3
	Overhang PF (3)	NR	NR	NR	NR	NR	NR	Table 506.5.1(1)	Table C407.5.1(1)
	Doors								
	Door Type	Swinging	Swinging	Swinging	Swinging	Swinging	Swinging	Table 506.5.1(1)	Table C407.5.1(1)
	U-factor (Btu/h·ft²·°F)	0.7	0.61	0.7	0.61	0.7	0.61	Table 502.2(1)	Table C402.2
	Infiltration								
	Provision of Air Barrier	NA	NR	NA	NR	NA	Mandatory	Section 502.4	Section C402.4
Lighting									
	Lighting Power Density (W/ft²)	1.0 W/ft²	0.9 W/ft²	1.0 W/ft²	0.9 W/ft²	1.0 W/ft²	0.9 W/ft²	Table 505.5.2	Table C406.3
HVAC System (VAV w/ reheat)									
	Chiller Specifications								
	Type/Capacity (4)	Screw ≥150 tons < 300 tons	Screw ≥150 tons < 300 tons	Screw ≥75 tons < 150 tons	Screw ≥75 tons < 150 tons	Screw ≥150 tons < 300 tons	Screw ≥150 tons < 300 tons	Table 506.5.1(3)	Table C407.5.1(3)
	Efficiency (COP and IPLV)(4)	Path A: 5.17 COP, 6.06 IPLV	Path B: 4.90 COP, 6.51 IPLV	Path A: 5.17 COP, 6.06 IPLV	Path B: 4.90 COP, 6.51 IPLV	Path A: 4.54 COP, 5.72 IPLV	Path B: 4.45 COP, 6.00 IPLV	Path A: 4.54 COP, 5.72 IPLV	Path B: 4.45 COP, 6.00 IPLV	Path A: 5.17 COP, 6.06 IPLV	Path B: 4.90 COP, 6.51 IPLV	Path A: 5.17 COP, 6.06 IPLV	Path B: 4.90 COP, 6.51 IPLV	Table 503.2.3(7)	Table C403.2.3(7)
	Boiler								
	Type/Capacity (4)	Hot water, Gas-fired ≥300 kBtu/hr ≤ 2,500 kBtu/hr	Hot water, Gas-fired ≥300 kBtu/hr ≤ 2,500 kBtu/hr	Hot water, Gas-fired ≥300 kBtu/hr ≤ 2,500 kBtu/hr	Hot water, Gas-fired ≥300 kBtu/hr ≤ 2,500 kBtu/hr	Hot water, Gas-fired ≥300 kBtu/hr ≤ 2,500 kBtu/hr	Hot water, Gas-fired ≥300 kBtu/hr ≤ 2,500 kBtu/hr	Table 506.5.1(3)	Table C407.5.1(3)
	Efficiency	75% Et	80% Et	75% Et	80% Et	75% Et	80% Et	Table 503.2.3(5)	Table C403.2.3(5)
	Fan Power								
	Type	VAV	VAV	VAV	VAV	VAV	VAV	Table 506.5.1(3)	Table C407.5.1(3)
	hp/1,000 cfm Supply	1.5	1.5	1.5	1.5	1.5	1.5	Table 503.2.10.1(1)	Table C403.2.10.1(1)
	Economizer								
	Minimum System Size for Which an Economizer is Required	2a: NR 2b: ≥ 54 kBtu/h	≥ 33 kBtu/h	≥ 54 kBtu/h	≥ 33 kBtu/h	≥ 54 kBtu/h	≥ 33 kBtu/h	Table 503.3.1(1)	Table C403.3.1(1)
SWH									
	Type/Capacity	Gas storage >75,000 Btu/hr ≤ 155,000 Btu/hr		Gas storage >75,000 Btu/hr ≤ 155,000 Btu/hr		Gas storage >75,000 Btu/hr ≤ 155,000 Btu/hr		Note	Note
	Efficiency	80% Et	80% Et	80% Et	80% Et	80% Et	80% Et	Table 504.2	Table C404.2

NOTES:

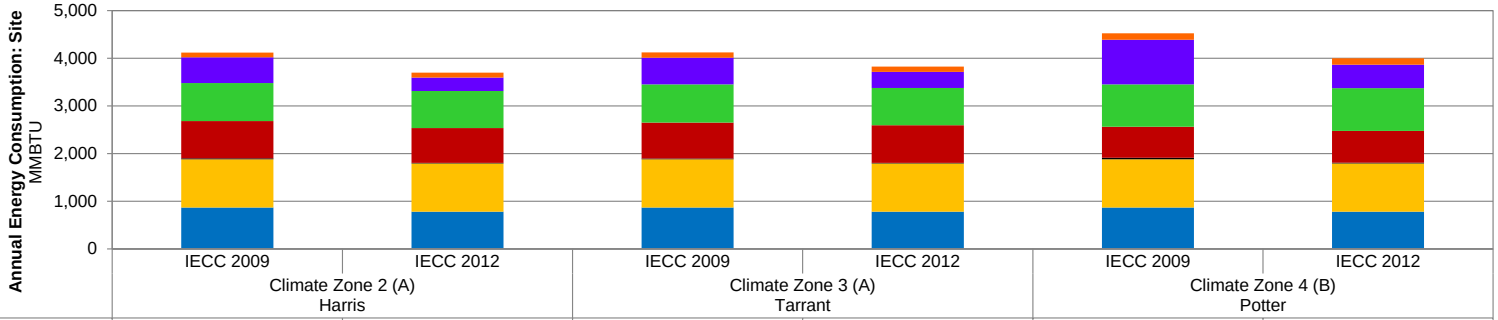
1. IEAD=Insulation Entirely Above Deck.
2. NR means that there are no minimum requirements for the corresponding category and NA means that this requirement is not applicable and cannot be used for compliance.
3. PF = Projection Factor
4. Sizing runs performed using ASHRAE specifications for design day.
5. Compliance of chiller performance requirements shall be demonstrated by meeting the minimum requirements of either Path A or B. However, both the full load and IPLV must be met to fulfill the requirements of Path A or B. For the purpose of this analysis the requirements of Path A are adopted.

Table 16: Comparison of Annual Energy Consumption: Site

Building Energy Performance Summary: Site Energy Consumption (MMBtu)						
	Climate Zone 2 (A) Harris		Climate Zone 3 (A) Tarrant		Climate Zone 4 (B) Potter	
End-Use Category	**IECC 2009**	**IECC 2012**	**IECC 2009**	**IECC 2012**	**IECC 2009**	**IECC 2012**
Area Lights ELEC	866	779	866	779	866	779
Misc. Equip. ELEC	1,013	1,013	1,013	1,013	1,013	1,013
Space Heat. ELEC	20	11	18	12	31	18
Space Cool. ELEC	782	730	754	789	653	664
Heat Reject. ELEC	262	248	247	235	230	221
Pumps/Misc. ELEC	203	198	216	212	251	246
Vent. Fans ELEC	335	332	340	337	409	430
Other ELEC	800	779	802	784	890	897
Space Heat. GAS	537	282	561	336	936	493
SHW GAS	102	102	110	110	134	134
ELECTRICITY	**3,480**	**3,312**	**3,452**	**3,378**	**3,453**	**3,371**
GAS	**640**	**385**	**670**	**446**	**1,070**	**627**
TOTAL	**4,120**	**3,696**	**4,122**	**3,823**	**4,523**	**3,998**
% DIFF. W/ 2009 CODE	-	**10%**	**-**	**7%**	**-**	**12%**

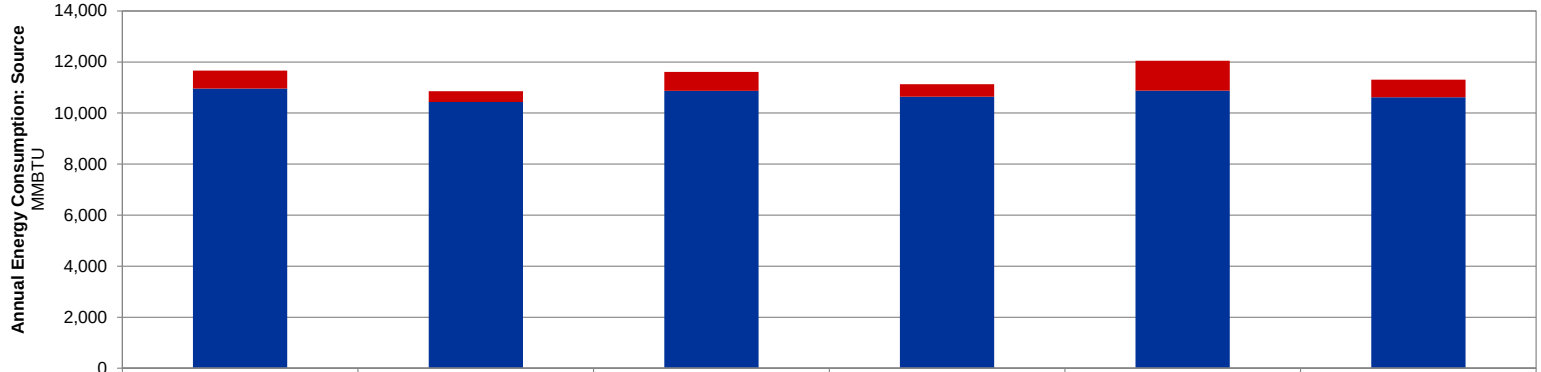
Table 17: Comparison of Annual Energy Consumption: Source

Source Energy Consumption (MMBtu)						
	Climate Zone 2 (A) Harris		Climate Zone 3 (A) Tarrant		Climate Zone 4 (B) Potter	
End-Use	**IECC 2009**	**IECC 2012**	**IECC 2009**	**IECC 2012**	**IECC 2009**	**IECC 2012**
ELECTRICITY	**10,963**	**10,432**	**10,874**	**10,639**	**10,876**	**10,619**
GAS	**703**	**423**	**737**	**490**	**1,177**	**689**
TOTAL	**11,667**	**10,855**	**11,611**	**11,130**	**12,053**	**11,308**
% DIFF. W/ 2009 CODE	**-**	**7%**	**-**	**4%**	**-**	**6%**



	IECC 2009	IECC 2012	IECC 2009	IECC 2012	IECC 2009	IECC 2012
	Climate Zone 2 (A) Harris		Climate Zone 3 (A) Tarrant		Climate Zone 4 (B) Potter	
TOTAL	4,120	3,696	4,122	3,823	4,523	3,998
GAS	640	385	670	446	1,070	627
ELECTRICITY	3,480	3,312	3,452	3,378	3,453	3,371
SHW GAS	102	102	110	110	134	134
Space Heat. GAS	537	282	561	336	936	493
Other ELEC	800	779	802	784	890	897
Space Cool. ELEC	782	730	754	789	653	664
Space Heat. ELEC	20	11	18	12	31	18
Misc. Equip. ELEC	1,013	1,013	1,013	1,013	1,013	1,013
Area Lights ELEC	866	779	866	779	866	779

Figure 2: Comparison of Annual Energy Consumption: Site



	IECC 2009	IECC 2012	IECC 2009	IECC 2012	IECC 2009	IECC 2012
	Climate Zone 2 (A) Harris		Climate Zone 3 (A) Tarrant		Climate Zone 4 (B) Potter	
TOTAL	11,667	10,855	11,611	11,130	12,053	11,308
GAS	703	423	737	490	1,177	689
ELECTRICITY	10,963	10,432	10,874	10,639	10,876	10,619

Figure 3: Comparison of Annual Energy Consumption: Source

6. REFERENCES

Ahmad, M., Gilman, D., Kim, S., Chongcharoensuk, C., Malhotra, M., Haberl, J., Culp, C. 2005. Development of a Web-based Emissions Reduction Calculator for Code-compliant Commercial Construction. Proceedings of the International Conference for Enhanced Building Operations. Pittsburgh, Pennsylvania.

Hirsch, J. J. 2010. *eQUEST, Quick Energy Simulation Tool: Introductory Tutorial*. James J. Hirsch and Associates. Camarillo, CA. [http://doe2.com/download/equest/eQ-v3-64_Introductory-Tutorial.pdf] (Accessed: 01/18/2012).

IECC, 2009. International Energy Conservation Code. International Code Council, Inc.

IECC, 2012. International Energy Conservation Code. International Code Council, Inc.

Kim, S.,Haberl, J., Liu, Z. 2009. Development of DOE-2-Based Simulation Models for the Code-Compliant Commercial Construction Based on the ASHRAE Standard 90.1. Proceedings of the Ninth International Conference for Enhanced Building Operations, Austin, Texas.

Leach, M., Lobato, M., Hirsch, M., Pless, S., Torcellini, P. 2010. Technical Support Document for 50% Energy Savings in Large Office Buildings. Technical Report NREL/TP – 550-49213. National Renewable Energy Laboratory, Golden, Colorado.

Winkelmann, F.C., B.E. Birdsall, W.F. Buhl, K.L. Ellington, A.E. Erdem, J.J.Hirsch, and S. Gates. 1993. *DOE-2 Supplement, Version 2.1e*. LBL-34947. Berkeley, CA: Regents of the University of California, Lawrence Berkley Laboratory.

Mukhopadhyay, J., Baltazar, J., Kim, H. and Haberl, J. 2011. Comparison of ASHRAE Standard 90.1, 189.1 and IECC Codes for Large Office Buildings in Texas. ESL-TR-11-08-02. Energy Systems Laboratory, Texas A&M University.

APPENDIX A: Assessing the Stringency of Section: C402.3.3.2, C402.3.3.3 and C402.3.3.4 of the 2012 IECC.

This section of the report assesses the stringency of Section C402.3.3.2, C402.3.3.3 and Section C402.3.3.4 of the 2012 International Energy Conservation Code (IECC).

A.1 Stringency of Section: C402.3.3.2 of the 2012 IECC.

Section C402.3.3.2 allows increased vertical fenestration in Climate Zones 1, 2 and 3 to have a maximum SHGC of 0.4 when the fenestration is entirely located above 6 feet. A designer using the 2012 IECC would need to raise the stringency in the other aspects of the building to compensate for this.

A.2 Stringency of Section: C402.3.3.3 and C402.3.3.4 of the 2012 IECC.

Section C402.3.3.3 allows increased SHGC for skylights in Climate Zones 1 through 6 when the skylights are located over a daylight zone provided with automatic daylighting control. Section C402.3.3.4 allows increased U-factors for skylights in Climate Zones1through 8 when the skylights are located over a daylight zone provided with automatic daylighting control. The concern was that for that for higher climate zones of Texas (i.e. Climate Zone 4), increasing the SHGC and U-values of skylights could render the 2012 IECC less stringent than the corresponding base-line without the installed daylighting controls. A building that uses skylights that comply with this section would need to raise the stringency in other aspects of the building to compensate for this.

A.3 Base Case

In order to assess the stringency of the sections described above, a simulation suite was conducted using a small office building as the base-case. The simulation was conducted using the appropriate weather file for Harris, Tarrant and Potter County which represents Climate Zones 2, 3 and 4 respectively for the State of Texas. eQUEST (Version 3.64) (Hirsch 2010) whole building simulation program was used to conduct the analysis. The office building has an area of 4000 ft^2. The building has a window to wall area ratio of 30% with the windows equally distributed in the four orientations. 3% of the roof area is covered with skylights. No daylight controls are simulated in the base-case model. Other specifications and assumptions for the base-case model are presented in Table A1 below. Table A1 also presents corresponding specifications provided in the 2009 IECC.

A.4 Simulations Matrix and Results

Table A-2 and Table A-3 present the results of the two test cases that are simulated to verify the stringency of the 2012 IECC code for Section C402.3.3.2.

- The test cases involve shifting the position of vertical fenestration to a sill height of 6 ft as compared to a sill height of 3ft in the base-case.
- The simulations have been performed for Climate Zones 2 and 3.
- The SHGC of the vertical fenestration was changed from 0.25 to 0.4 for both the climate zones. The two cases include running the simulation with and without daylighting controls.

Corresponding graphs are presented in Figure A-1 and Figure A-2.

It is observed that for both the test cases, the annual cooling energy is higher than that of the base-case building. On the other hand the annual heating energy for the two cases is lower than that of the base-case building. The resultant overall annual energy consumption for cases with daylighting control is lower than that of the base-case. While the resultant overall annual energy consumption for cases without daylighting control is similar to that of the base-case.

Table A-4, Table A-5 and Table A-6 present the results of the four test cases that are simulated to perform the assessment for Climate Zones 2, 3 and 4 respectively. The test cases involve modeling higher values of SHGC (from 0.4 to 0. 6), higher U-factors (from 0.5 to 0.75) and higher skylight areas (from 3% to 5% of roof area). For the three tables:

- The first three test cases simulate daylighting control. The next three cases do not simulate daylighting control.
- The first test case simulates a higher SHGC value (from 0.4 to 0. 6) for skylights in addition to the installed daylighting controls.
- The second test case simulated a larger skylight (from 3% to 5% of roof area) in addition to the higher SHGC value and installed daylight control.
- The third test case simulates a higher U-value (from 0.5 to 0.75) in addition to higher SHGC and installed daylighting controls.
- The fourth test case simulates a bigger skylight (from 3% to 5% of roof area) in addition to the modifications in the third test case.
- The fifth test case simulates a higher SHGC value (from 0.4 to 0. 6) for skylights.
- The sixth test case simulated a larger skylight (from 3% to 5% of roof area) in addition to the higher SHGC value.
- The seventh test case simulates a higher U-value (from 0.5 to 0.75) in addition to higher SHGC.
- The eighth test case simulates a bigger skylight (from 3% to 5% of roof area) in addition to the modifications in the seventh test case.

On observing the results, the assessment concludes that with the installation of daylighting controls, increasing the SHGC and U-factors of skylights does not render the 2012 IECC code to be less stringent than the corresponding 2012 IECC base-line without the installed daylighting controls. Corresponding graphs are presented in Figure A-2, Figure A-3 and Figure A-4 below.

Table A- 1: Description of the 2009 and 2012 IECC Specifications for Small Office Building

Building Component		Climate Zone 2 (A,B) Harris		Climate Zone 3 (A,B) Tarrant		Climate Zone 4B Potter		References	
		IECC 2009	IECC 2012	IECC 2009	IECC 2012	IECC 2009	IECC 2012	IECC 2009	IECC 2012
Envelope									
	Exterior Walls								
	Construction Type	Steel frame	Steel frame	Steel frame	Steel frame	Steel frame	Steel frame	Table 506.5.1(1)	Table C407.5.1(1)
	R-value (h·ft²·°F/Btu)	R-13	R-13 + R-5.0 c.i.	R-13 + R-3.8 c.i.	R-13 + R-7.5 c.i.	R-13 +R-7.5 c.i.	R-13 +R-7.5 c.i.	Table 502.2(1)	Table C402.2
	Roof								
	Construction Type	IEAD (1)	IEAD	IEAD	IEAD	IEAD	IEAD	Table 506.5.1(1)	Table C407.5.1(1)
	R-value (h·ft²·°F/Btu)	R-20 c.i.	R-20 c.i.	R-20 c.i.	R-20 c.i.	R-20 c.i.	R-25 c.i.	Table 502.2(1)	Table C402.2
	Reflectance	0.25	0.25	0.25	0.25	0.25	0.25	Table 506.5.1(1)	Table C407.5.1(1)
	Emittance	0.9	0.9	0.9	0.9	0.9	0.9	Table 506.5.1(1)	Table C407.5.1(1)
	Floor / Slab								
	Consturction Type	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Slab-on-Grade, Unheated	Table 506.5.1(1)	Table C407.5.1(1)
	R-value (h·ft²·°F/Btu)	NR (2)	NR	NR	NR	NR	R-10 for 2' below	Table 502.2(1)	Table C402.2
	Windows								
	Maximum WWR %	40%	40%	40%	40%	40%	40%	Table 506.5.1(1)	Table C407.5.1(1)
	Framing Type	Metal framing	Fixed	Metal framing	Fixed	Metal framing	Fixed		
	U-factor (Btu/h·ft²·°F)	U-0.75	U-0.50	U-0.65	U-0.46	U-0.55	U-0.38	Table 502.3	Table C402.3
	SHGC	0.25	0.25	0.25	0.25	0.40	0.40	Table 502.3	Table C402.3
	Overhang PF (3)	NR	NR	NR	NR	NR	NR	Table 506.5.1(1)	Table C407.5.1(1)
	Skylights								
	U-factor (Btu/h·ft²·°F)	0.75	0.5	0.65	0.46	0.60	0.38		Table C402.3
	SHGC	0.35	0.25	0.35	0.25	0.40	0.4		Table C402.3
	Doors								
	Door Type	Swinging	Swinging	Swinging	Swinging	Swinging	Swinging	Table 506.5.1(1)	Table C407.5.1(1)
	U-factor (Btu/h·ft²·°F)	0.7	0.61	0.7	0.61	0.7	0.61	Table 502.2(1)	Table C402.2
	Infiltration								
	Provision of Air Barrier	NA (0.244 ACH)	NR (0.244 ACH)	NA (0.244 ACH)	NR (0.244 ACH)	NA (0.244 ACH)	Mandatory (0.054 ACH)	Section 502.4 Leach et al. 2010	Section C402.4 Leach et al. 2010
Lighting									
	Lighting Power Density (W/ft²)	1.0 W/ft²	0.9 W/ft²	1.0 W/ft²	0.9 W/ft²	1.0 W/ft²	0.9 W/ft²	Table 505.5.2	Table C406.3
HVAC System (VAV w/ reheat)									
	Unitary Air Conditioners								
	Type/Capacity (4)	≥ 65 kBtu/hr < 130 kBtu/hr	≥ 65 kBtu/hr < 130 kBtu/hr	≥ 65 kBtu/hr < 130 kBtu/hr	≥ 65 kBtu/hr < 130 kBtu/hr	≥ 65 kBtu/hr < 130 kBtu/hr	≥ 65 kBtu/hr < 130 kBtu/hr	Table 506.5.1(3)	Table C407.5.1(3)
	Efficiency (EER) Fan efficiency (?)	11 / 11	11 / 11	11 / 11	11 / 11	11 / 11	11 / 11	Table 503.2.3(2)	Table C406.2(1)
	Warm Air Furnace Specs.								
	Type/Capacity (4)	Warm air furnace, Gas-fired > 225 kBtu/hr	Warm air furnace, Gas-fired > 225 kBtu/hr	Warm air furnace, Gas-fired > 225 kBtu/hr	Warm air furnace, Gas-fired > 225 kBtu/hr	Warm air furnace, Gas-fired > 225 kBtu/hr	Warm air furnace, Gas-fired > 225 kBtu/hr	Table 506.5.1(3)	Table C407.5.1(3)
	Efficiency	80% Et	80% Et	80% Et	80% Et	80% Et	80% Et	Table 503.2.3(4)	Table C403.2.3(5)
	Economizer								
	Minimum System Size for Which an Economizer is Required	2a: NR 2b: ≥ 54 kBtu/h	≥ 33 kBtu/h	≥ 54 kBtu/h	≥ 33 kBtu/h	≥ 54 kBtu/h	≥ 33 kBtu/h	Table 503.3.1(1)	Table C403.3.1(1)
SWH									
	Type/Capacity (5)	Gas storage ≤75,000 Btu/hr		Gas storage ≤75,000 Btu/hr		Gas storage ≤75,000 Btu/hr			
	Efficiency	0.67-0.019V	0.67-0.019V	0.67-0.019V	0.67-0.019V	0.67-0.019V	0.67-0.019V	Table 504.2	Table C404.2

NOTES:

1. IEAD=Insulation Entirely Above Deck.
2. NR means that there are no minimum requirements for the corresponding category and NA means that this requirement is not applicable and cannot be used for compliance.
3. PF = Projection Factor
4. Sizing runs performed using ASHRAE specifications for design day.
5. The volume of the service water heater was assumed to be 50 gallons.

Table A- 2: Annual Energy Consumption Results for Test-Cases Regarding C402.3.3.2 (Climate Zone – 2A)

Test Case (Ref: Note)	From eQUEST											
	Electricity (kWhr/yr)						Gas (kBtu/yr)			Elec (MMBtu/yr)	Gas (MMBtu/yr)	Total (MMBtu/yr)
	Cool	Pumps & Aux.	Ext. Usage	Misc. Equip.	Area Lights	Total	Heat	SHW	Total			
2012 Base-Case	12417	65	14017	8471	10165	45135	35187	1754	36941	154	37	**191**
With Daylighting Control (w/ DC)												
SH: 6ft	13334	65	14017	8471	4503	40390	32126	1754	33880	138	34	**172**
Without Daylighting Control (w/o DC)												
SH: 6ft	14461	65	14017	8471	10165	47179	29002	1754	30756	161	31	**192**

Note:
SH: Sill Height

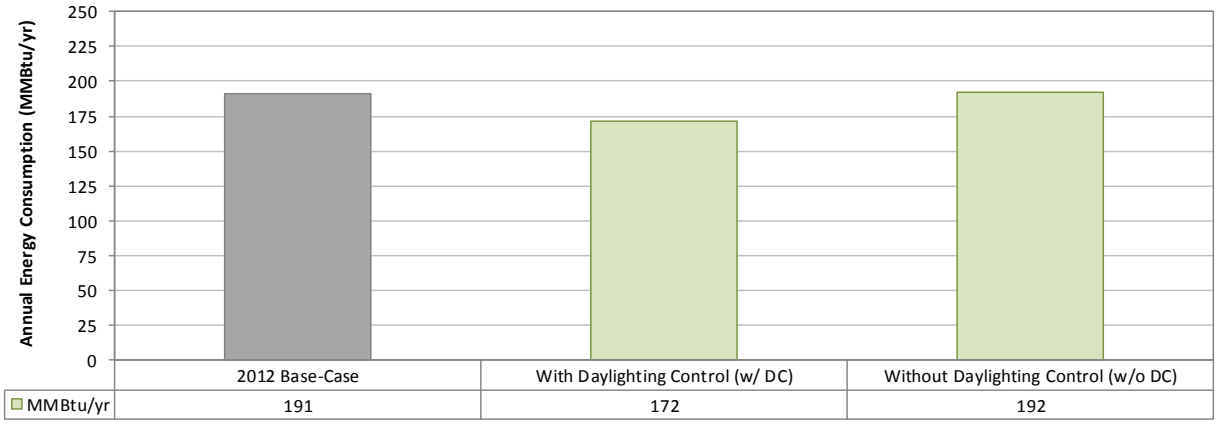


Figure A- 1: Annual Energy Consumption Results for Test-Cases Regarding C402.3.3.2 (Climate Zone – 2A)

Table A- 3: Annual Energy Consumption Results for Test-Cases Regarding C402.3.3.2 (Climate Zone – 3A)

Test Case (Ref: Note)	From eQUEST											
	Electricity (kWhr/yr)						Gas (kBtu/yr)			Elec (MMBtu/yr)	Gas (MMBtu/yr)	Total (MMBtu/yr)
	Cool	Pumps & Aux.	Ext. Usage	Misc. Equip.	Area Lights	Total	Heat	SHW	Total			
2012 Base-Case	10751	95	13874	8471	10165	43355	50660	1909	52569	148	53	**201**
With Daylighting Control (w/ DC)												
SH: 6ft	11750	95	13874	8471	4497	38686	45072	1909	46981	132	47	**179**
Without Daylighting Control (w/o DC)												
SH: 6ft	12703	95	13874	8471	10165	45308	40755	1909	42664	155	43	**197**

Note:
SH: Sill Height

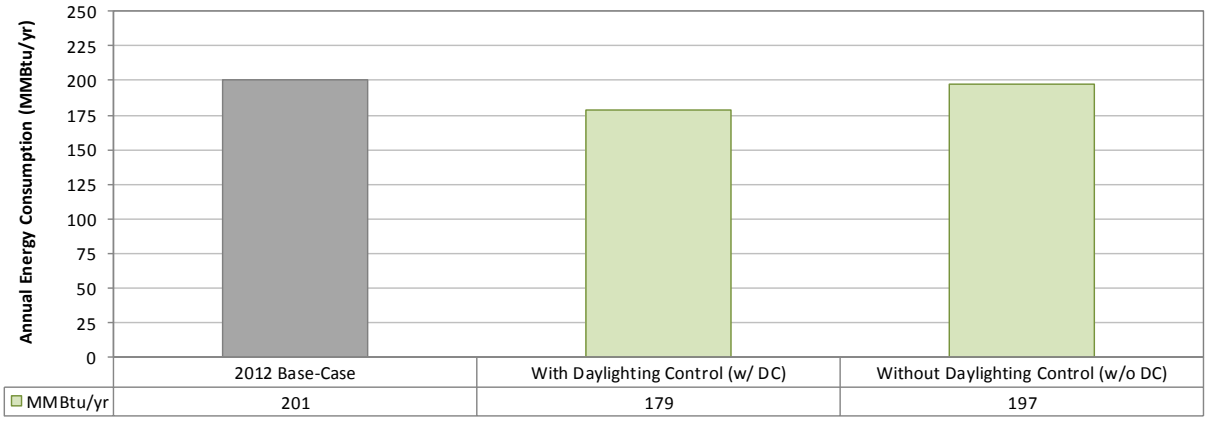


Figure A- 2: Annual Energy Consumption Results for Test-Cases Regarding C402.3.3.2 (Climate Zone – 3A)

Table A- 4: Annual Energy Consumption Results for Test-Cases regarding Section C402.3.3.3 and C402.3.3.4 (Climate Zone – 2A)

Test Case (Ref: Note)	From eQUEST											
	Electricity (kWhr/yr)						Gas (kBtu/yr)			Elec (MMBtu/yr)	Gas (MMBtu/yr)	Total (MMBtu/yr)
	Cool	Pumps & Aux.	Ext. Usage	Misc. Equip.	Area Lights	Total	Heat	SHW	Total			
2012 Base-Case	12417	65	14017	8471	10165	45135	35187	1754	36941	154	37	**191**
With Daylighting Control (w/ DC)												
3%,SC	11921	65	14017	8471	4590	39063	37612	1754	39367	133	39	**173**
5%,SC	12838	65	14017	8471	4538	39928	38259	1754	40013	136	40	**176**
3%,SC,U	11927	65	14017	8471	4590	39069	38083	1754	39838	133	40	**173**
5%,SC,U	12851	65	14017	8471	4538	39941	39039	1754	40794	136	41	**177**
Without Daylighting Control (w/o DC)												
3%,SC	13041	65	14017	8471	10165	45759	33938	1754	35692	156	36	**192**
5%,SC	13955	65	14017	8471	10165	46673	34636	1754	36390	159	36	**196**
3%,SC,U	13046	65	14017	8471	10165	45763	34383	1754	36138	156	36	**192**
5%,SC,U	13965	65	14017	8471	10165	46683	35462	1754	37216	159	37	**197**

Note:

3%,SC: 3% of roof area covered with skylights; SHGC: 0.6.

5%, SC: 5% of roof area covered with skylights; SHGC: 0.6.

3%, SC: 3% of roof area covered with skylights; U-value: 0.75.

3%, SC: 5% of roof area covered with skylights; U-value: 0.75.

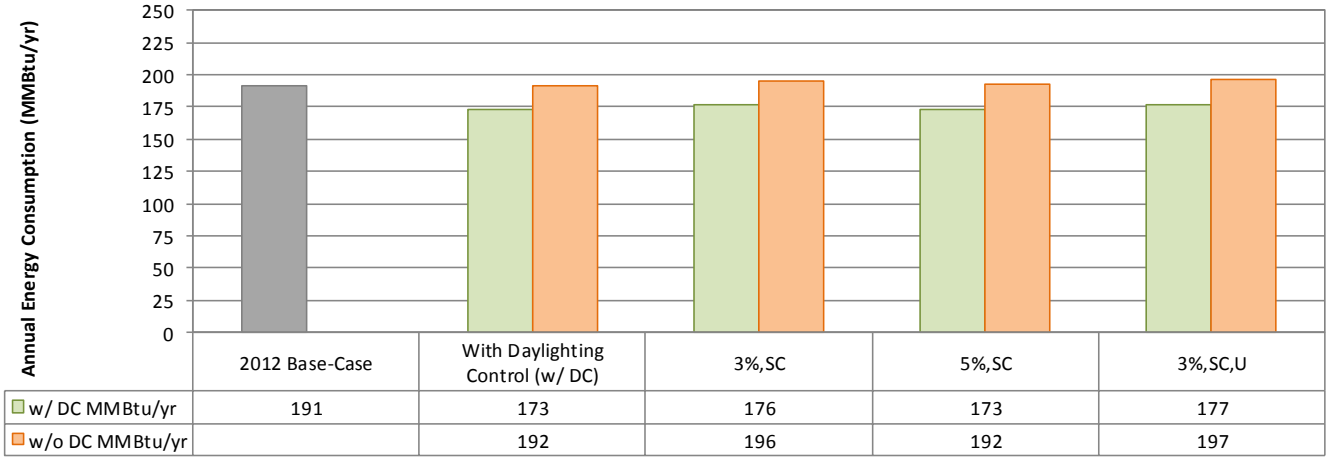


Figure A- 3: Annual Energy Consumption Results for Test-Cases regarding Section C402.3.3.3 and C402.3.3.4 (Climate Zone – 2A)

Table A- 5: Annual Energy Consumption Results for Test-Cases regarding Section C402.3.3.3 and C402.3.3.4 (Climate Zone – 3A)

Test Case (Ref: Note)	From eQUEST											
	Electricity (kWhr/yr)						Gas (kBtu/yr)			Elec (MMBtu/yr)	Gas (MMBtu/yr)	Total (MMBtu/yr)
	Cool	Pumps & Aux.	Ext. Usage	Misc. Equip.	Area Lights	Total	Heat	SHW	Total			
2012 Base-Case	10751	95	13874	8471	10165	43355	50660	1909	52569	148	53	**201**
With Daylighting Control (w/ DC)												
3%,SC	10416	95	13874	8471	4571	37427	54114	1909	56023	128	56	**184**
5%,SC	11364	95	13874	8471	4526	38329	54638	1909	56547	131	57	**187**
3%,SC,U	10433	95	13874	8471	4571	37444	55540	1909	57449	128	57	**185**
5%,SC,U	11392	95	13874	8471	4526	38357	57126	1909	59035	131	59	**190**
Without Daylighting Control (w/o DC)												
3%,SC	11369	95	13874	8471	10165	43973	48905	1909	50814	150	51	**201**
5%,SC	12307	95	13874	8471	10165	44911	49491	1909	51400	153	51	**205**
3%,SC,U	11384	95	13874	8471	10165	43988	50336	1909	52245	150	52	**202**
5%,SC,U	12335	95	13874	8471	10165	44939	51965	1909	53874	153	54	**207**

Note:

3%,SC: 3% of roof area covered with skylights; SHGC: 0.6.

5%, SC: 5% of roof area covered with skylights; SHGC: 0.6.

3%, SC: 3% of roof area covered with skylights; U-value: 0.75.

3%, SC: 5% of roof area covered with skylights; U-value: 0.75.

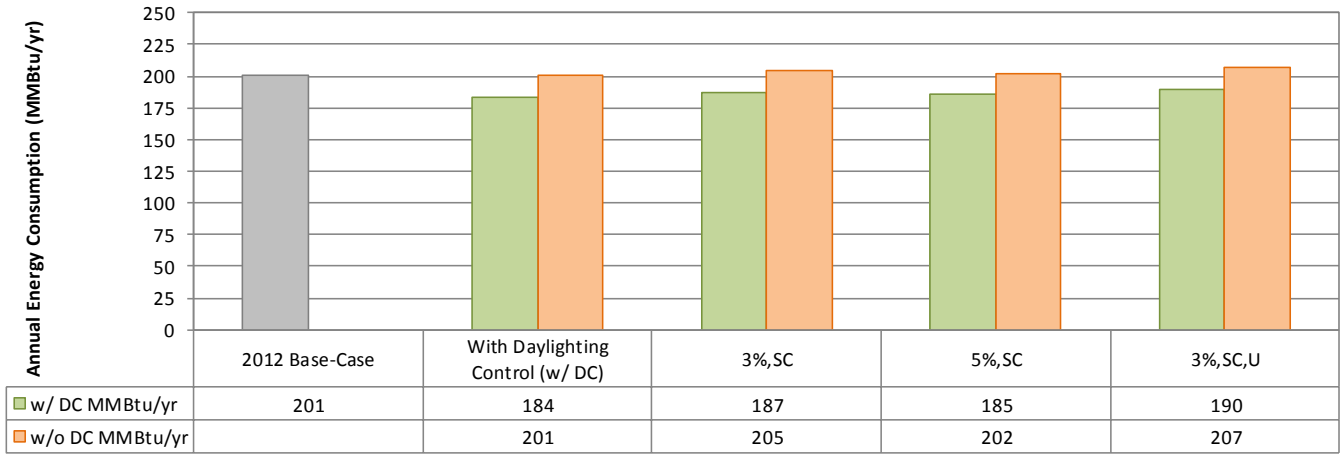


Figure A- 4: Annual Energy Consumption Results for Test-Cases regarding Section C402.3.3.3 and C402.3.3.4 (Climate Zone – 3A)

Table A- 6: Annual Energy Consumption Results for Test-Cases regarding Section C402.3.3.3 and C402.3.3.4 (Climate Zone – 4B)

Test Case (Ref: Note)	From eQUEST											
	Electricity (kWhr/yr)						Gas (kBtu/yr)			Elec (MMBtu/yr)	Gas (MMBtu/yr)	Total (MMBtu/yr)
	Cool	Pumps & Aux.	Ext. Usage	Misc. Equip.	Area Lights	Total	Heat	SHW	Total			
2012 Base-Case	7506	180	13537	8471	10165	39859	89806	2258	92064	136	92	**228**
With Daylighting Control (w/ DC)												
3%,SC	7200	180	13537	8471	4551	33939	94447	2258	96705	116	97	**213**
5%,SC	7914	180	13537	8471	4512	34614	96371	2258	98629	118	99	**217**
3%,SC,U	7206	180	13537	8471	4551	33945	98099	2258	100357	116	100	**216**
5%,SC,U	7919	180	13537	8471	4512	34618	102521	2258	104779	118	105	**223**
Without Daylighting Control (w/o DC)												
3%,SC	7894	180	13537	8471	10165	40246	87615	2258	89873	137	90	**227**
5%,SC	8610	180	13537	8471	10165	40963	89631	2258	91889	140	92	**232**
3%,SC,U	7894	180	13537	8471	10165	40247	91166	2258	93424	137	93	**231**
5%,SC,U	8615	180	13537	8471	10165	40968	95565	2258	97824	140	98	**238**

Note:

3%,SC: 3% of roof area covered with skylights; SHGC: 0.6.

5%, SC: 5% of roof area covered with skylights; SHGC: 0.6.

3%, SC: 3% of roof area covered with skylights; U-value: 0.75.

3%, SC: 5% of roof area covered with skylights; U-value: 0.75.

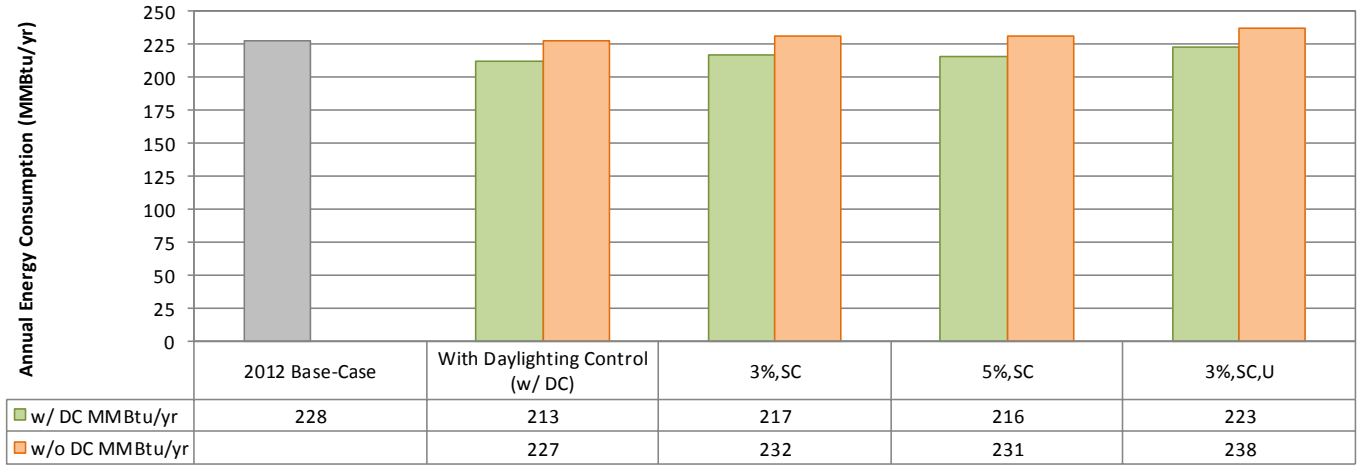


Figure A- 5: Annual Energy Consumption Results for Test-Cases regarding Section C402.3.3.3 and C402.3.3.4 (Climate Zone – 4B)